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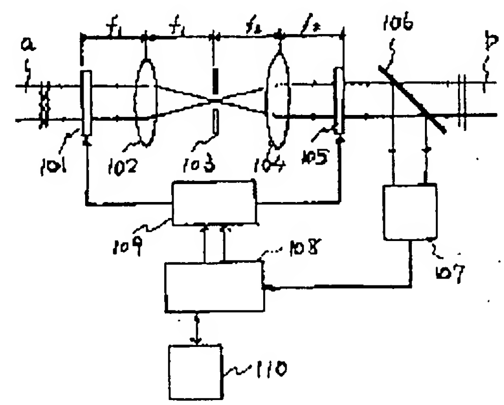
(54) OPTICAL DEVICE

(57)Abstract:
PURPOSE: To correct the amplitude and phase of a light wave front at the same time by optically connecting a liquid crystal element for amplitude modulation and a liquid crystal element for phase modulation to each other.

CONSTITUTION: The liquid crystal element 101 for amplitude modulation imposes amplitude modulation on a laser beam (a) to be corrected and then the liquid crystal element 105 for phase modulation imposes phase modulation. Those liquid crystal elements 101 and 105 are connected in mutually conjugate relation by an afocal optical system consisting of a lens 102 and a lens 104. A spatial filter 103 removes diffracted higher order components generated when the beam is transmitted through the liquid crystal elements. The beam transmitted through the liquid crystal elements is guided partially to an aberration measurement system 107 by a mirror 106. The rest exits from the device as a beam (b) having its amplitude distribution and phase distribution corrected. The aberration measurement system 107 and a driving circuit 109 for the liquid crystal elements are connected to a computer 108. Correction information matching the purpose of use of the device is inputted to the driving circuit 109 to stop down the beam to the limit of diffraction.



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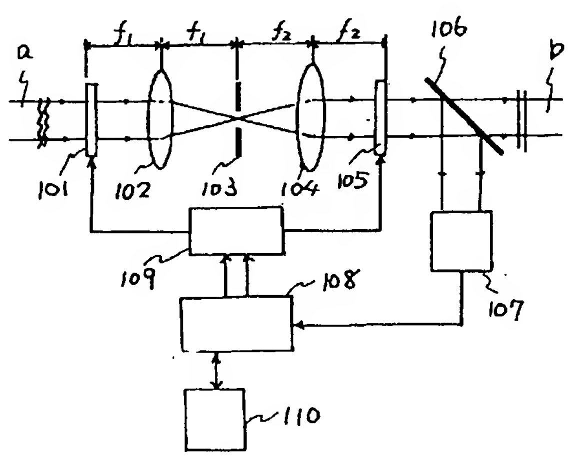
(54)【発明の名称】　光学装置

(57)【要約】

【目的】　光波面の振幅と位相を制御する光学装置を提供する。

【構成】　振幅変調用液晶素子と、位相変調用液晶素子と、これら液晶素子の駆動回路と、光波面の位相分布を測定する手段と、この手段により得られた光波面の位相分布の情報を液晶素子の駆動回路へ帰還する回路を備えていることを特徴とする。



【特許請求の範囲】

【請求項１】光波面の振幅と位相を補正する技術に関し、液晶素子と、前記液晶素子の駆動回路と、光波面の位相分布を測定する手段と、前記光波面を測定する手段により得られた信号を前記液晶素子の駆動回路へ帰還する回路を備えて成ることを特徴とする光学装置。

【請求項２】振幅変調用液晶素子と、位相変調用液晶素子と、前記複数の液晶素子の駆動回路を備えて成ることを特徴とする請求項１に記載の光学装置。

【請求項３】振幅変調用液晶素子と位相変調用液晶素子の間にアフォーカル光学系を備え、前記振幅変調用液晶素子と前記位相変調用液晶素子が前記アフォーカル光学系において互いに共役な関係で配置されて成ることを特徴とする請求項１ないし２に記載の光学装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、液晶素子を応用した光学装置に関する。

【０００２】

【従来の技術】従来、光波面の位相分布を補正する目的には、１枚続きのミラーの形状を裏からアクチュエータで変形させる方式が広く利用されていた。変形させるアクチュエータにはピエゾ素子が使われ、ストロークが数μｍ、個数が５００個程度のものが試作されている（例えば、Ｐｒｏｃ．ＳＰＩＥ，Ｖｏｌ．１１１４，ｐ１３４（１９８９）参照）。

【０００３】

【発明が解決しようとする課題】しかし、ピエゾ素子には、発熱、ヒステリシスなどの制御に工夫がいる、素子数が限られている、駆動電圧が高いなどの問題点があった。

【０００４】本発明はこのような問題点を解決するものであって、その目的は、簡便な手段により光波面の位相分布を測定、補正して、かつ同時に光波面の振幅分布を補正することができる光学装置を提供するところにある。

【０００５】

【課題を解決するための手段】本発明の第１の光学装置は、液晶素子と、前記液晶素子の駆動回路と、光波面の位相分布を測定する手段と、前記光波面を測定する手段により得られた信号を前記液晶素子の駆動回路へ帰還する回路を備えて成ることを特徴とする。

【０００６】本発明の第２の光学装置は、前記第１の光学装置において、振幅変調用液晶素子と、位相変調用液晶素子と、前記複数の液晶素子の駆動回路を備えて成ることを特徴とする。

【０００７】本発明の第３の光学装置は、前記第１ないし第２の光学装置において、振幅変調用液晶素子と位相変調用液晶素子の間にアフォーカル光学系を備え、前記振幅変調用液晶素子と前記位相変調用液晶素子が前記アフォーカル光学系において互いに共役な関係で配置されて成ることを特徴とする。

【０００８】

【実施例】以下では実施例にもとづき、本発明の内容について詳しく説明する。

【０００９】（実施例１）直線偏光レーザビームの波面補正を例にあげる。図１に本実施例の光学装置の構成を示す。補正されるべきレーザビームａは、振幅変調用液晶素子１０１で振幅変調を受けた後に、位相変調用液晶素子１０５で位相変調を受ける。これらふたつの液晶素子は、レンズ１０２とレンズ１０４から構成されるアフォーカル光学系により、互いに共役に接続されている。空間フィルタ１０３は、ビームが液晶素子を透過する時に発生する高次回折成分を除くために配置されている。液晶素子を透過したビームは、ミラー１０６により一部は収差測定系１０７へ導かれる。残りは振幅分布ならびに位相分布が補正されたビームｂとなって装置の外へ出てゆく。収差測定系１０７ならびに液晶素子の駆動回路１０９は、コンピュータ１０８に接続されている。

【００１０】液晶素子の駆動回路には、装置の用途に合わせて、補正情報を入力する。たとえば、ガウス関数形の振幅分布を与える補正情報を振幅変調用液晶素子１０１へ入力し、同時に、光波面、レンズ系および液晶素子の各収差の総和に対して複素共役な位相分布を与える補正情報を位相変調用液晶素子１０５へ入力する。こうすると、ビームを回折限界近くまで絞ることができる。この他にも、計算機ホログラムの手法を用いて前記補正情報の作り方を工夫することにより、集光スポットを複数発生させたり、任意の集光強度分布を得ることができる（第５１回応用物理学会学術講演会予稿集２６ａ－Ｈ－１０）。振幅分布に関する補正情報およびレンズ系や液晶素子の各収差から求めた位相分布に関する補正情報は、あらかじめコンピュータに接続されたメモリ１１０に格納しておいてもよい。

【００１１】収差測定系１０７はレンズアレイと光検出器を備え、集光スポットの位置から光波面の収差を測定する。そして、測定の結果をもとに、位相変調用液晶素子１０５の各画素へ加えるべき電圧値を算出して、これを補正情報として駆動回路１０９へ帰還する。駆動回路は、受け取った補正情報にしたがって、通過する光の位相を画素単位で制御する。光波面の収差の測定には、ジャックハルトマン法（Ｐｕｂｌ．Ｎａｔ．Ａｓｔｒｏｎ．Ｏｂｓ．，Ｖｏｌ．１，ｐ４９（１９８９）参照）やロジェ法（Ｐｒｏｃ．ＳＰＩＥ，Ｖｏｌ．１１１４，ｐ９２（１９８９）参照）が用いられる。

【００１２】本実施例には、ＴＮ（ツイストネマッティック）モードの振幅変調用液晶素子と、ＥＣＢ（電界制御複屈折）モードの位相変調用液晶素子を用いた。どちらの液晶素子も、各画素にＴＦＴ（薄膜トランジスタ）を備えたマトリクス駆動型の液晶素子であって、５ボル

ト程度の低い電圧で駆動できる。有効画素数は３２０×２２０、画素間隔は水平方向８０μｍ、垂直方向９０μｍである。

【００１３】位相変調液晶素子における液晶分子の配向はホモジニアス配向であって、ビーム波面の位相を連続的に変調することができる（第５１回応用物理学会学術講演会予稿集２６ａ－Ｈ－１０）。ただし、ビームの直線偏光方位を液晶分子の配向方向に合わせておく必要がある。なお、ビームがＴＮモードの液晶素子を通過する時に受ける位相歪は（Ｊｐｎ．Ｊ．Ａｐｐｌ．Ｐｈｙｓ．，２９，Ｌ１５３３（１９９０）参照）、ＥＣＢモードの液晶素子を用いて補正する。

【００１４】本実施例によれば、振幅変調用液晶素子と位相変調用液晶素子を光学的に接続することにより、ビーム波面の収差を補正すると同時に所望の振幅分布をビームに与えることができる。液晶素子は低電圧駆動、低消費電力、高画素密度という特徴を備えており、従来のピエゾ素子に比べて容易にビーム波面の位相を制御することができる。

【００１５】なお、振幅変調用液晶素子と位相変調用液晶素子の順序を逆にして接続することも可能である。

【００１６】（実施例２）ランダム偏光レーザビームの波面補正を例にあげる。図２に本実施例の光学装置の構成を示す。収差を含むランダム偏光なビームａは、偏光ビームスプリッタ２０１で紙面に垂直な成分（Ｓ偏光）と紙面に平行な成分（Ｐ偏光）に分かれる。それぞれの成分は振幅変調用液晶素子２０２（または２０７）で振幅変調を受けた後、位相変調用液晶素子２０６（または２１１）で位相変調を受ける。振幅変調用液晶素子２０２と位相変調用液晶素子２０６は、レンズ２０３とレンズ２０５から構成されるアフォーカル光学系により、他方、振幅変調用液晶素子２０７と位相変調用液晶素子２１１は、レンズ２０８とレンズ２１０から構成されるアフォーカル光学系により、互いに共役に接続されている。ミラー２０４、２０９は、それぞれ液晶素子２０２、２０７を透過したビームの０次回折成分だけを反射させるように、局所的に反射率が高く、それ以外の領域には反射防止膜が付加されている。液晶素子を透過したビームは、偏光ビームスプリッタ２１２へ入射する。ここでふたつの成分は合成され、振幅分布ならびに位相分布が補正されたビームｂとなって装置の外へ出てゆく。ただし、ミラー１０６によりビームｂの一部は収差測定系１０７へ導かれる。収差測定系１０７ならびに液晶素子の駆動回路１０９は、コンピュータ１０８に接続されている。

【００１７】本実施例で使用した振幅変調用液晶素子および位相変調用液晶素子は、実施例実１で使用したものと同じである。また、収差測定系の構成ならびに収差測定方法も、互いに直交する直線偏光成分のそれぞれについて行う点を除いては実施例１と同様である。よって、ここでは説明を省略する。

【００１８】本実施例によれば、アフォーカル光学系で接続された振幅変調用液晶素子と位相変調用液晶素子の組を、互いに直交する直線偏光成分の各々に作用させることによって、ランダム偏光なビーム波面の収差を補正すると同時に所望の振幅分布をビームに与えることができる。

【００１９】

【発明の効果】本発明によれば、光波面の振幅と位相を同時に補正することができる。本発明の光学装置は、液晶素子のプログラム自在性を活用して、レーザビーム波面制御に代表される補償光学へ幅広く応用が可能である。

【図面の簡単な説明】

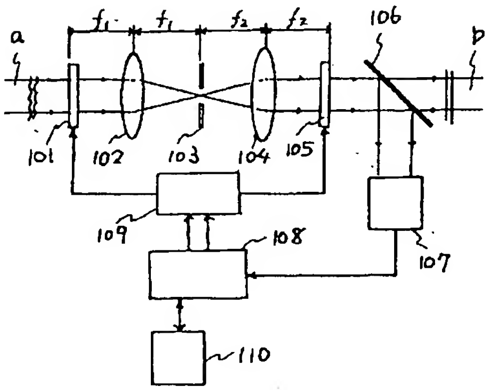
【図１】　本発明の実施例１の構成を示す平面図である。

【図２】　本発明の実施例２の構成を示す平面図である。

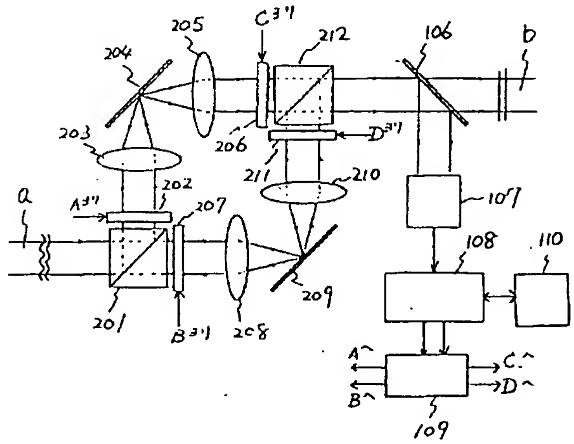
【符号の説明】

１０１……マトリクス駆動型のＴＮモード液晶素子
１０２……レンズ
１０３……空間フィルタ
１０４……レンズ
１０５……マトリクス駆動型のＥＣＢモード液晶素子
１０６……ミラー
１０７……収差測定系
１０８……コンピュータ
１０９……駆動回路
１１０……メモリ
２０１……偏光ビームスプリッタ
２０２……マトリクス駆動型のＴＮモード液晶素子
２０３……レンズ
２０４……ミラー
２０５……レンズ
２０６……マトリクス駆動型のＥＣＢモード液晶素子
２０７……マトリクス駆動型のＴＮモード液晶素子
２０８……レンズ
２０９……ミラー
２１０……レンズ
２１１……マトリクス駆動型のＥＣＢモード液晶素子
２１２……偏光ビームスプリッタ

【図1】


a
b
f_1
f_1
f_2
f_2
106
101
102
103
104
105
109
108
107
110

【図2】


a
b
205
204
C へ
212
106
203
206
D へ
211
210
107
202
A へ
207
108
110
201
B へ
208
209
A へ
B へ
C へ
D へ
109

* NOTICES *

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] this invention relates to the optical equipment adapting the liquid crystal device.
[0002]
[Description of the Prior Art] Conventionally, the method into which the configuration of the mirror of the one-sheet continuation by the phase distribution of a light wave side is made to deform with an actuator from the reverse side was widely used for the amendment purpose. A piezo-electric element is used for the actuator made to deform, and that whose number a stroke is several micrometers and is about 500 pieces is made as an experiment (for example, Proc.SPIE, Vol.1114, p134 (1989) reference).
[0003]
[Problem(s) to be Solved by the Invention] However, there were troubles, like the driver voltage which requires a device for control of generation of heat, a hysteresis, etc. and to which the element number is restricted is high in a piezo-electric element.
[0004] that to which this invention solves such a trouble -- it is -- a means with the simple purpose -- the phase distribution of a light wave side -- measurement -- rectifying -- and -- simultaneous -- the amplitude distribution of a light wave side -- an amendment -- it is in the place which offers the optical equipment which can do things
[0005]
[Means for Solving the Problem] The 1st optical equipment of this invention is characterized by having the circuit which returns the signal acquired by the liquid crystal device, the drive circuit of the aforementioned liquid crystal device, means to measure the phase distribution of a light wave side, and means to measure the aforementioned light wave side to the drive circuit of the aforementioned liquid crystal device, and changing.
[0006] The 2nd optical equipment of this invention is characterized by having the drive circuit of the liquid crystal device for amplitude modulation, the liquid crystal device for phase modulations, and two or more aforementioned liquid crystal devices, and changing in the optical equipment of the above 1st.
[0007] The 3rd optical equipment of this invention is characterized by having afocal optical system between the liquid crystal device for amplitude modulation, and the liquid crystal device for phase modulations, arranging mutually the aforementioned liquid crystal device for amplitude modulation, and the aforementioned liquid crystal device for phase modulations by the conjugate relation in the aforementioned afocal optical system, and changing in the above 1st or the 2nd optical equipment.
[0008]
[Example] Below, based on an example, the content of this invention is explained in detail.
[0009] (Example 1) A wave-front amendment of a linearly polarized light laser beam is mentioned as an example. The composition of the optical equipment of this example is shown in drawing 1 . The laser beam a which should be rectified receives a phase modulation by the liquid crystal device 105 for phase modulations, after receiving amplitude modulation by the liquid crystal device 101 for amplitude modulation. These two liquid crystal devices are mutually connected to conjugate by the afocal optical system which consists of a lens 102 and a lens 104. The spatial filter 103 is arranged in order to remove the high order diffraction component generated when a beam penetrates a liquid crystal device. A part is led to the aberration system of measurement 107 for the beam which penetrated the liquid crystal device by the mirror 106. The remainder serves as the beam b with which the phase distribution was rectified by the amplitude-distribution row, and is left out of equipment. The drive circuit 109 of a liquid crystal device is connected to the computer 108 at the aberration system-of-measurement 107 row.
[0010] Amendment information is inputted into the drive circuit of a liquid crystal device according to the use of equipment. For example, the amendment information which gives the amplitude distribution of gauss function type is inputted into the liquid crystal device 101 for amplitude modulation, and the amendment information which gives a complex conjugate phase distribution to total of each aberration of a light wave side, a lens system, and a liquid crystal device is simultaneously inputted into the liquid crystal device 105 for phase modulations. If it carries out like this, a beam can be extracted to near the diffraction limitation. In addition, by devising how making the aforementioned amendment information using the technique of a computer generated hologram, two or more condensing spots can be generated, or arbitrary condensing intensity distributions can be obtained (collection of 51st Japan Society of Applied Physics academic lecture meeting drafts 26 a-H -10). You may store the amendment information about the phase distribution for which it asked from each aberration of the amendment information and lens system about an amplitude distribution, or a liquid crystal device in the memory 110 beforehand connected to the computer.
[0011] The aberration system of measurement 107 is equipped with a lens array and a light sensitive cell, and measures the

aberration of a light wave side from the position of a condensing spot. And the voltage value which should be applied to each pixel of the liquid crystal device 105 for phase modulations is computed based on the result of measurement, and it returns to the drive circuit 109 by making this into amendment information. A drive circuit controls the phase of the passing light per pixel according to the received amendment information. The jack Hartmann method (Publ.Nat.Astron.Obs., Vol.1, p49 (1989) reference) and the Roget method (Proc.SPIE, Vol.1114, p92 (1989) reference) are used for measurement of the aberration of a light wave side.

[0012] The liquid crystal device for amplitude modulation in TN (twist NEMATTIKKU) mode and the liquid crystal device for phase modulations in ECB (electric-field control birefringence) mode were used for this example. Both of the liquid crystal devices are matrix drive type liquid crystal devices which equipped each pixel with TFT (TFT), and can be driven on the low voltage of about 5 volts. The number of effective pixels is 320x220, and pixel intervals are 80 micrometers of horizontal directions, and 90 micrometers of perpendicular directions.

[0013] The orientation of the liquid crystal molecule in a phase modulation liquid crystal device is homogeneous orientation, and can modulate the phase of a beam wave front continuously (collection of 51st Japan Society of Applied Physics academic lecture meeting drafts 26 a-H -10). However, it is necessary to double the linearly polarized light direction of a beam in the direction of orientation of a liquid crystal molecule. In addition, the phase distortion received when a beam passes the liquid crystal device in TN mode is amended using the liquid crystal device in (Jpn.J.Appl.Phys., 29, L1533 (1990) reference), and ECB mode.

[0014] According to this example, a desired amplitude distribution can be given to a beam for the aberration of a beam wave front simultaneously with an amendment by connecting optically the liquid crystal device for amplitude modulation, and the liquid crystal device for phase modulations. The liquid crystal device is equipped with the feature of a low-battery drive, a low power, and high pixel density, and can control the phase of a beam wave front easily compared with the conventional piezo-electric element.

[0015] In addition, it is also possible to make reverse sequence of the liquid crystal device for amplitude modulation and the liquid crystal device for phase modulations, and to connect.

[0016] (Example 2) A wave-front amendment of a random polarization laser beam is mentioned as an example. The composition of the optical equipment of this example is shown in drawing 2 . The beam [**** / at random] a including aberration is divided into a component (S polarization) perpendicular to space, and a component (P polarization) parallel to space in a polarization beam splitter 201. Each component receives a phase modulation by the liquid crystal device 206 (or 211) for phase modulations, after receiving amplitude modulation by the liquid crystal device 202 (or 207) for amplitude modulation. Another side, the liquid crystal device 207 for amplitude modulation, and the liquid crystal device 211 for phase modulations are mutually connected to conjugate with the afocal optical system which consists of a lens 208 and a lens 210 by the afocal optical system with which the liquid crystal device 202 for amplitude modulation and the liquid crystal device 206 for phase modulations consist of a lens 203 and a lens 205. A reflection factor is locally high and the antireflection film is added to the other field so that mirrors 204 and 209 may reflect only the zero-order diffraction component of the beam which penetrated liquid crystal devices 202 and 207, respectively. Incidence of the beam which penetrated the liquid crystal device is carried out to a polarization beam splitter 212. Two components are compounded, serve as the beam b with which the phase distribution was rectified by the amplitude-distribution row, and are left out of equipment here. However, a part of beam b is led to the aberration system of measurement 107 by the mirror 106. The drive circuit 109 of a liquid crystal device is connected to the computer 108 at the aberration system-of-measurement 107 row.

[0017] The liquid crystal device for amplitude modulation and the liquid crystal device for phase modulations which were used by this example are the same as what was used substantially [example / 1]. Moreover, if an aberration measuring method also removes the point performed about each of the linearly polarized light component which intersects perpendicularly mutually in the composition row of aberration system of measurement, it is the same as that of an example 1 in it. Therefore, explanation is omitted here.

[0018] According to this example, a desired amplitude distribution can be given to a beam for the aberration of a beam wave front [**** / at random] simultaneously with an amendment by making the group of the liquid crystal device for amplitude modulation connected with afocal optical system, and the liquid crystal device for phase modulations act on each of the linearly polarized light component which intersects perpendicularly mutually.

[0019]

[Effect of the Invention] according to this invention -- the amplitude and phase of a light wave side -- simultaneous -- an amendment -- things are made The optical equipment of this invention can utilize the program free nature of a liquid crystal device, and can apply it broadly to the phase conjugation optics represented by laser beam wave-front control.

[Translation done.]

CLAIMS

[Claim(s)]
[Claim 1] Optical equipment characterized by to have the circuit which returns the signal acquired by means measure a liquid crystal device, the drive circuit of the aforementioned liquid crystal device, and the phase distribution of a light wave side for the amplitude and phase of a light wave side about amendment technology, and means measure the aforementioned light wave side to the drive circuit of the aforementioned liquid crystal device, and to change.
[Claim 2] Optical equipment according to claim 1 characterized by having the drive circuit of the liquid crystal device for amplitude modulation, the liquid crystal device for phase modulations, and two or more aforementioned liquid crystal devices, and changing.
[Claim 3] The claim 1 characterized by having afocal optical system between the liquid crystal device for amplitude modulation, and the liquid crystal device for phase modulations, arranging mutually the aforementioned liquid crystal device for amplitude modulation, and the aforementioned liquid crystal device for phase modulations by the conjugate relation in the aforementioned afocal optical system, and changing, or optical equipment given in 2.

[Translation done.]